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09-12-2000  
525 Rec'd PCT/PTO

11 SEP 2000

09/623924

CHAPTER II

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Date of Deposit September 11, 2000

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MICHAEL BURNS

**TRANSMITTAL LETTER  
TO THE UNITED STATES ELECTED OFFICE (EO/US)  
(ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)**

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE
PCT/DE99/00268	1 February 1999	10 March 1998

TITLE OF INVENTION  
MEASURING DEVICE WITH A MICROSENSOR AND METHOD FOR ITS PRODUCTION

APPLICANT  
WERNER, Wolfgang

**Box PCT  
Assistant Commissioner for Patents  
Washington D.C. 20231  
ATTENTION: EO/US**

1. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. 371:
  - a. ☒ This express request to immediately begin national examination procedures (35 U.S.C. 371(f)).
  - b. ☒ The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

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## 2. Fees

CLAIMS FEE	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
<input type="checkbox"/> *	TOTAL CLAIMS	22 - 20 =	2	x \$ 18.00 =	\$36.00
	INDEPENDENT CLAIMS	2 - 3 =	0	x \$ 78.00 =	
	MULTIPLE DEPENDENT CLAIM(S) (if applicable) + \$270.00				
BASIC FEE**	<input type="checkbox"/> U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where an International preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO: <input type="checkbox"/> and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(2) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 CFR 1.492(a)(4)) ..... \$98.00 <input type="checkbox"/> and the above requirements are not met (37 CFR 1.492(a)(1)) ..... \$720.00  <input checked="" type="checkbox"/> U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO: <input type="checkbox"/> has been paid (37 CFR 1.492(a)(2)) ..... \$790.00 <input type="checkbox"/> has not been paid (37 CFR 1.492(a)(3)) ..... \$1,070.00 <input checked="" type="checkbox"/> where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 CFR 1.492(a)(5)) ..... \$840.00				
	Total of above Calculations = \$876.00				
SMALL ENTITY	Reduction by ½ for filing by small entity, if applicable. Affidavit must be filed. (note 37 CFR 1.9, 1.27, 1.28)				
	Subtotal				
	Total National Fee \$876.00				
	Fee for recording the enclosed assignment document \$40.00 (37 CFR 1.21(h)). (See Item 13 below). See attached "ASSIGNMENT COVER SHEET".				
TOTAL	Total Fees enclosed \$876.00				

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\*See attached Preliminary Amendment Reducing the Number of Claims.

- i. ☒ A check in the amount of \$876.00 to cover the above fees is enclosed.
  - ii. ☐ Please charge Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_.  
A duplicate copy of this sheet is enclosed.
3. ☒ A copy of the International application as filed (35 U.S.C. 371(c)(2)):
  - a. ☒ is transmitted herewith.
  - b. ☐ is not required, as the application was filed with the United States Receiving Office.
  - c. ☐ has been transmitted
    - i. ☐ by the International Bureau.  
Date of mailing of the application (from form PCT/IB/308): \_\_\_\_\_.
    - ii. ☐ by applicant on \_\_\_\_\_.  
Date
4. ☒ A translation of the International application into the English language (35 U.S.C. 371(c)(2)):
  - a. ☐ is transmitted herewith.
  - b. ☐ is not required as the application was filed in English.
  - c. ☐ was previously transmitted by applicant on \_\_\_\_\_.  
Date
  - d. ☒ will follow.
5. ☐ Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. 371(c)(3)):
  - a. ☐ are transmitted herewith.
  - b. ☐ have been transmitted
    - i. ☐ by the International Bureau.  
Date of mailing of the amendment (from form PCT/IB/308): \_\_\_\_\_.
    - ii. ☐ by applicant on \_\_\_\_\_.  
Date
  - c. ☐ have not been transmitted as
    - i. ☐ applicant chose not to make amendments under PCT Article 19.  
Date of mailing of Search Report (from form PCT/ISA/210): \_\_\_\_\_.
    - ii. ☐ the time limit for the submission of amendments has not yet expired. The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.
6. ☐ A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. 371(c)(3)):
  - a. ☐ is transmitted herewith.
  - b. ☐ is not required as the amendments were made in the English language.
  - c. ☐ has not been transmitted for reasons indicated at point 5(c) above.
7. ☒ A copy of the international examination report (PCT/IPEA/409)

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- ☒ is transmitted herewith.  
☐ is not required as the application was filed with the United States Receiving Office.
8. ☐ Annex(es) to the international preliminary examination report  
a. ☐ is/are transmitted herewith.  
b. ☐ is/are not required as the application was filed with the United States Receiving Office.
9. ☐ A translation of the annexes to the international preliminary examination report  
a. ☐ is transmitted herewith.  
b. ☐ is not required as the annexes are in the English language.
10. ☒ An oath or declaration of the inventor (35 U.S.C. 371(c)(4)) complying with 35 U.S.C. 115  
a. ☐ was previously submitted by applicant on \_\_\_\_\_.  
Date  
b. ☒ is submitted herewith, and such oath or declaration  
i. ☒ is attached to the application.  
ii. ☐ identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. 1.70.  
iii. ☐ will follow.
- Other document(s) or information included:
11. ☒ An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):  
a. ☒ is transmitted herewith.  
b. ☐ has been transmitted by the International Bureau.  
Date of mailing (from form PCT/IB/308): \_\_\_\_\_.  
c. ☐ is not required, as the application was searched by the United States International Searching Authority.  
d. ☐ will be transmitted promptly upon request.  
e. ☐ has been submitted by applicant on \_\_\_\_\_.  
Date
12. ☐ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98:  
a. ☐ is transmitted herewith.  
Also transmitted herewith is/are:  
☐ Form PTO-1449 (PTO/SB/08A and 08B).  
☐ Copies of citations listed.  
b. ☐ will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. 371(c).  
c. ☐ was previously submitted by applicant on \_\_\_\_\_.  
Date
13. ☐ An assignment document is transmitted herewith for recording.

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A separate ☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING  
NEW PATENT APPLICATION" or ☐ FORM PTO  
1595 is also attached.

14. ☒ Additional documents:
- a. ☐ Copy of request (PCT/RO/101)
  - b. ☒ International Publication No. WO 99/46605
    - i. ☐ Specification, claims and drawing
    - ii. ☒ Front page only
  - c. ☐ Preliminary amendment (37 C.F.R. § 1.121)
  - d. ☐ Other

15. ☒ The above checked items are being transmitted
- a. ☒ before 30 months from any claimed priority date.
  - b. ☐ after 30 months.

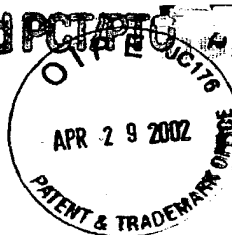
  
SIGNATURE OF PRACTITIONER

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070201



Docket No.: GR 98 P 1307

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By: 

Date: April 18, 2002

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Wolfgang Werner  
Applic. No. : 09/623,924  
Filed : September 11, 2000  
Title : Measuring Apparatus with Microsensor and  
Method for Producing it

P R E L I M I N A R Y A M E N D M E N T

Hon. Commissioner of Patents and Trademarks,  
Washington, D. C. 20231

S i r :

Preliminary to the examination of the instant application,  
kindly amend the above-identified application as follows:

In the Translated Specification:

Page 1, line 3, delete "Description".

Page 1, replace the paragraph beginning on line 5 with the  
following: --MEASURING APPARATUS WITH MICROSENSOR AND METHOD  
FOR PRODUCING IT--.

Page 1, between lines 6 and 8, insert:

--Background of the Invention:

Field of the Invention:--.

Page 2, between lines 15 and 17, insert:

--Summary of the Invention:--.

Page 2, replace the paragraph beginning on line 26 with the following paragraph:

--This object is achieved by a measuring apparatus and a production method according to the claims.--

Page 8, above line 1, insert:

--Brief Description of the Drawings:--.

Page 8, between lines 12 and 14, insert:

--Description of the Preferred Embodiments:--.

Page 17, at the top, change the heading "Patent Claims" to --I Claim:--.

In the Claims:

Please cancel claims 1 to 23.

Enter the Following New Claims:

--24. A measuring apparatus, comprising:

at least one microsensor having:

at least two chambers gastightly sealed off to the environment and filled with a gas;

a channel fluidically connecting said at least two chambers to one another; and

a detection device disposed in said channel for detecting a gas stream flowing in said channel due to different pressures prevailing in said at least two chambers.

25. The measuring apparatus according to claim 24, wherein:

said detection device has a heating/cooling element; and

said detection device is at least one of heated and cooled by said heating/cooling element to a measurement temperature differing from a temperature of said gas in said chambers.

26. The measuring apparatus according to claim 24, wherein:

said detection device has an output; and

said detection device supplies an electrical measurement signal at said output in reaction to a detected change in a temperature of said detection device, the change in temperature taking place due to said gas stream flowing between said chambers through said channel.

27. The measuring apparatus according to claim 24, wherein said heating/cooling element is one of the group consisting of an electrical heating resistor, a heating transistor, and a heating diode.

28. The measuring apparatus according to claim 24, wherein said heating/cooling element is a Peltier element.

29. The measuring device according to claim 24, wherein said detection device is a thermoelement.

30. The measuring apparatus according to claim 24, wherein said detection device is a heating/cooling element.

31. The measuring apparatus according to claim 24, including:

a reference channel opening only in one of said at least two chambers; and

a reference detection device having predetermined electrical properties and being disposed at said reference channel.

32. The measuring apparatus according to claim 24, wherein:

said detection device includes an additional detection device with predetermined electrical properties and an output;

said additional detection device is at least one of heated and cooled by the gas stream and:

supplies an electrical measurement signal at said output in reaction to an altering of the gas stream temperature by said detection device at a measurement temperature when the gas stream travels in a direction from said detection device to said additional detection device; and

supplies no measurement signal at said output when the gas stream travels in a direction from said additional detection device to said detection device.

33. The measuring apparatus according to claim 31, wherein said detection device and said reference detection device are connected together in a measuring bridge circuit.

34. The measuring apparatus according to claim 31, wherein:

said microsensor has at least one wall with an edge region;  
and

both said detection device and said reference detection device  
are disposed at said edge region of said wall.

35. The measuring apparatus according to claim 34, wherein  
both said detection device and said reference detection device  
are disposed in said edge region of said wall.

36. The measuring apparatus according to claim 34, wherein  
both said detection device and said reference detection device  
are disposed on said edge region of said wall.

37. The measuring apparatus according to claim 31, wherein:

said microsensor has at least one wall; and

both said detection device and said reference detection device  
are formed of said wall.

38. The measuring apparatus according to claim 32, wherein:

said microsensor has at least one wall with an edge region;  
and

both said detection device and said additional detection device are disposed at said edge region of said wall.

39. The measuring apparatus according to claim 38, wherein both said detection device and said additional detection device are disposed in said edge region of said wall.

40. The measuring apparatus according to claim 38, wherein both said detection device and said additional detection device are disposed on said edge region of said wall.

41. The measuring apparatus according to claim 32, wherein:  
  
said microsensor has at least one wall; and

both said detection device and said additional detection device are formed of said wall.

42. The measuring apparatus according to claim 34, wherein  
  
said wall is of semiconductor material.

43. The measuring apparatus according to claim 38, wherein  
  
said wall is of semiconductor material.

44. The measuring apparatus according to claim 24, wherein:

at least one of said chambers and said channel are formed in said substrate.

said reference channel is formed in said substrate.

46. The measuring apparatus according to claim 32, wherein said additional detection device is disposed at said channel.

47. The measuring apparatus according to claim 24, wherein at least one of said chambers has an elastic diaphragm effecting the gastight seal from the environment.

48. The measuring apparatus according to claim 24, wherein:

said microsensor is a plurality of microsensors disposed in a matrix in rows and columns; and

said microsensors are to be driven by a drive circuit.

49. A method for producing a measuring apparatus having at least one microsensor, which further comprises:

forming a measuring device monolithically in a substrate by:

forming at least two chambers with at least one channel connecting the chambers;

forming a detection device in the channel for detecting a gas stream flowing in the channel, the gas stream arising due to different pressures prevailing in the chambers;

filling the chambers and the channel with a gas;

gastightly closing the chambers with respect to the environment; and

forming a reference channel opening only into one of the chambers.

50. The method according to claim 49, which further comprises carrying out the closing step by flowing a covering material over the chambers, the channel, and the reference channel and not fully filling any one of the chambers, the channel, or the reference channel.

51. The method according to claim 50, which further comprises carrying out the closing step by flowing the covering material in the presence of a gas intended to fill the chambers and the channel in the filling step.

52. The method according to claim 50, wherein the covering material is of borophosphorus silicate glass.

53. The method according to claim 49, which further comprises:

fabricating each of:

the chambers;

the channel;

the reference channel;

the detection device;

a reference detection device; and

at least one additional detection device,

in the substrate according to the following steps:

to the channel 40 in the semiconductor substrate 10, and is connected only to the chamber 30, with the result that a gas stream cannot form in it. The reference channel 50 has essentially the same cross section as the channel 40. Its length is somewhat shorter, however, with the result that the reference channel 50 ends before the other chamber 20.

In order to preclude the temperature influences of the microsensor, the resistor 70 with the resistor 60 can be incorporated together in a bridge circuit (not specifically illustrated), with the result that only a gas flow between the chambers can generate a corresponding signal.

The resistors 60, 70 and 80 can, in principle, be composed of any desired material. In particular, metals or highly doped semiconductors are suitable as materials for the resistors. The use of highly doped semiconductor materials for the resistors 60, 70 and 80 has the advantage that the resistors 60, 70 and 80 can be produced particularly simply in the process for the production of the integrated circuit comprising the measuring apparatus.

It is also possible for the detection device 70 and/or the reference 60 and additional detection device 80 to be arranged or formed in front of an opening in the channel 40 and/or reference channel 50, respectively. The detection device 70 and/or the reference 60 and additional detection device 80 may, furthermore, be formed or identified by a partial region of the semiconductor material of the channel 40 and/or of the reference channel 50, respectively, said semiconductor material forming the wall, or be formed or identified by a partial region of the semiconductor material forming the wall which lies in front of an opening in a channel 40.

The production method comprises the steps which are illustrated in more detail in Figures 3A to 3C:

According to Figure 3A, a support layer 10A, preferably  
5 composed of silicon, is covered with a first sacrificial layer 11, composed of  $\text{SiO}_2$ . The first sacrificial layer 11 preferably has a thickness of between  $0.5 \mu\text{m}$  and  $5 \mu\text{m}$ .

Afterwards, in accordance with Figure 3A, an electrically  
10 conductive patterning layer 12 is deposited for the purpose of forming resistors 60, 70, 80. This layer is preferably composed of doped polycrystalline silicon. The patterning layer 12 is patterned using photolithography and etching methods which are known from semiconductor technology. The  
15 patterning is preferably effected such that both the resistors 60, 70 and 80 and their leads 61, 63, 71, 73, 81 and 83 are produced.

After the formation of the resistors 60, 70 and 80 and the  
20 leads 61, 63, 71, 73, 81 and 83, a second sacrificial layer 13 is deposited in accordance with Figure 3B. The second sacrificial layer 13 preferably has the same thickness as the first sacrificial layer 11.

25 In accordance with Figure 3B, a covering layer 14 is applied to the second sacrificial layer 13. The covering layer 14 is composed of polycrystalline silicon, for example. Using photolithography and etching methods which are likewise known from semiconductor technology, the covering layer 14 is  
30 provided in regions with etching openings 15, under which a cavity 16 in the form of chambers or channels is fabricated in a subsequent process step.

In the Abstract:

Please replace the Abstract of the Disclosure with the new Abstract of the Disclosure, attached hereto as a separate sheet.

Remarks:

This preliminary amendment is being submitted in an effort to correct informalities and provide improved translations of certain wording in the initial application, and to present claims in proper U.S. claims idiom and to remove multiple dependencies. The changes are not made for any reason related to the statutory requirements for a patent nor do they narrow the scope of the claim for any reason related to the statutory requirements for a patent. The newly entered claims are fully supported in the original claims.

The recommended subheadings have been inserted at the proper locations in the text.

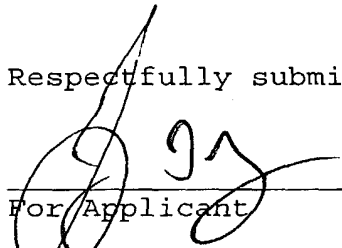
All of the changes are properly supported in the original application. No new matter has been added.

An early action on the merits of the application is solicited.

The fee for twelve (12) additional claims over twenty (20) pursuant to Section 1.16(c) in the amount of \$216.00 is enclosed herewith.

Please charge any fees that might be due with respect to Sections 1.16 and 1.17 to the Deposit Account of Lerner and Greenberg, P.A., No. 12-1099:

Respectfully submitted,

  
\_\_\_\_\_  
For Applicant

GLM/bb

Gregory L. Mayback  
Reg. No. 40,719

April 18, 2002

Lerner and Greenberg, P.A.  
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Version of the Specification With Markings to Show ChangesMade:

Page 1, replace the paragraph beginning on line 5 with the following paragraph: --[Title of the invention: Measuring apparatus with microsensor and method for producing it]

MEASURING APPARATUS WITH MICROSENSOR AND METHOD FOR PRODUCINGIT--.

Page 2, replace the paragraph beginning on line 26 with the following paragraph: --This object is achieved by [means of] a measuring apparatus [according to claim 1] and a production method [according to claim 18] according to the claims.--

**SECRET**

5 the chambers are sealed off to the outside in a gastight manner. Also provided is a detection device for detecting a gas stream flowing in the channel, which gas stream arises on account of different pressures prevailing in the chambers.

GLM

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# Description

- 5 Title of the invention: Measuring apparatus with microsensor  
and method for producing it

The invention relates to a measuring apparatus having at least  
one microsensor and also to a method for producing such a  
10 measuring apparatus.

Microsensors and, in particular, micromechanical sensors for  
pressure or acceleration have acquired major technological  
importance in integrated electronic circuits. The known  
15 microsensors are designed as piezoresistive or capacitive  
pressure sensors for absolute, relative and differential  
pressure measurements. They are based on the principle that a  
deformation body made of a semiconductor material is deformed  
under the action of a force.

20

WO 95/09366 discloses an acceleration sensor having a movable  
mass part which is connected to a suspension via spring  
elements. The movable mass part comprises a movable plate of a  
capacitor. The other, fixed plate of the capacitor is  
25 connected to the housing. Accelerations acting on the mass  
part lead to a deflection of the mass part and thus to a  
change in the capacitance of the capacitor. This change in  
capacitance can be detected.

30 Furthermore, pressure sensors are known in which a deformation  
body made of a semiconductor material is connected in its edge  
region to a base body. In this case, the deformation body is  
preferably designed as a thin diaphragm. One or more  
piezoresistive resistance tracks are arranged in those regions





In this case, in an advantageous refinement of the invention, the detection device may expediently be formed by the heating/cooling element itself.

A structurally particularly simple and therefore preferred embodiment of the invention is distinguished by the fact that the detection device is formed by a thermoelement.

A furthermore particularly preferred refinement of the invention provides for there to be a reference channel which opens only in a chamber, a reference detection device having predetermined electrical properties being assigned to said reference channel. In this case, it is advantageous that the influence of the temperature of the microsensor itself can be eliminated in circuitry terms by a comparison of the signals of the detection device and of the reference detection device.

In this case, a preferred refinement provides for the detection device and the reference detection device to be connected up in a measuring bridge circuit.

A further advantageous embodiment of the invention provides for an additional detection device having predetermined electrical properties to be assigned to the detection device. In this case, the additional detection device is heated or cooled by the heated or cooled gas stream, respectively, the temperature of which has been altered by the detection device at the measurement temperature, in the case of the gas stream direction from the detection device to the additional detection device, and, as a reaction to this, supplies an electrical measurement signal at its output and, in the case

In order to be able to detect the gas stream particularly well, a further embodiment of the invention provides for the detection device and/or the additional detection device to be formed within at least one channel.

In an advantageous refinement of the invention, both the detection device and the reference detection device or the additional detection device are arranged in or on an edge region of a wall or are formed so as to comprise the wall.

15 Accordingly, in a particularly preferred refinement of the invention, the wall is composed of semiconductor material.

It is furthermore preferable for the chambers and the channels and/or the reference channel of the microsensor to be formed in or on a semiconductor substrate. The advantage of this embodiment resides in the integrability of the measuring apparatus in an integrated circuit formed in a semiconductor substrate.

25 For the detection of an external pressure or a change in  
pressure, one embodiment of the invention provides an elastic  
diaphragm that effects sealing-off to the outside.

A furthermore preferred advantageous refinement of the invention is distinguished by the fact that a multiplicity of  
30 microensors are arranged in matrix form in rows and columns and can be driven individually by means of a drive circuit. In this case, it is advantageous that data of high resolution, which only becomes possible through the small size of the

microsensors, can be detected by means of the sensor in a planar manner.

The invention furthermore relates to a method for producing a microsensor formed monolithically in or on a substrate. In this case, provision is made for forming at least two chambers with at least one channel connecting the chambers, and also a reference channel which opens only into one chamber.

Afterwards, a detection device for detecting a gas stream flowing in the at least one channel is formed, which gas stream arises on account of different pressures prevailing in the chambers. In the next step, the chambers, the channels and the reference channel are filled with a gas and closed off to the outside in a gastight manner.

In a particularly preferred method step, the closure of the chambers and the at least one channel connecting the chambers is effected by the flowing of a covering material. In this case, the covering material is preferably of a nature such that the chambers and the channels and also the reference channel are not fully filled. In this case, in a furthermore preferred method step, the flowing of the covering material takes place in the presence of a gas intended for the filling of the chambers.

In a particularly preferred method, the chambers, the at least one channel connecting the chambers, and also the reference channel in or on the substrate and also the detection device and also the reference and the additional detection devices are fabricated by the following process steps:

- coating of the substrate with a sacrificial layer, which is composed, in particular, of  $\text{SiO}_2$ ,
- patterning of the detection device and also of the reference and the additional detection devices with their leads on the

sacrificial layer, in particular by means of an etching method,

- application of a second sacrificial layer,
- application of a first covering layer, in particular made of polycrystalline silicon,
- provision of the covering layer with holes at least partially in the regions under which the chambers and/or channels are intended to be produced, and
- etching out of the two sacrificial layers through the holes in the covering layer for the purpose of producing the chambers and/or channels.

In order to prevent diffusion of the gas into the semiconductor material forming the wall, it is expedient, in a further preferred method step, prior to the closure of the chambers, to provide at least a portion of those areas of the semiconductor substrate which face the chambers and/or of those areas of the semiconductor substrate which face the channel with a blocker layer. In this case, it is also advantageous that a reaction of the filling gas with the surfaces is prevented.

In addition to their advantageous properties and the fact that they can be produced easily, the microsensors according to the invention are also distinguished by their diverse application possibilities.

Thus, it is possible to use a microsensor according to the invention as an acceleration sensor, as a pressure sensor or as a temperature sensor.

Further advantages, special features and expedient developments of the invention emerge from the subclaims.

Figure 1 shows a schematic sectional view of a measuring  
5 apparatus having a microsensor according to the invention;

Figure 2 shows an enlarged detail of a partial region II from Figure 1; and

10    Figures 3A to 3C show schematic sectional views for  
elucidating a method for producing a microsensor according to  
the invention.

The measuring apparatus having at least one microsensor according to the invention may be configured either as an acceleration sensor, as a pressure sensor or as a temperature sensor. The same basic concept can be used in each of these configurations. In the case of the measuring apparatus according to the invention, the basic principle of the acceleration, pressure or temperature measurement is based on the detection of a gas stream which has arisen on account of the quantity to be measured. To that end, two chambers which are sealed off in a gastight manner and are filled with a gas are connected to one another by a channel. Through this channel, pressure differences prevailing in the two chambers are equalized by a gas stream that is established. In this case, the pressure difference can be achieved through an acceleration of the microsensor integrated in the measuring apparatus or a change in the temperature of the gas in a chamber. The gas stream is preferably detected directly in the channel connecting the chambers, by means of a detection device, and is converted into an electrical signal.

The exemplary embodiment - illustrated in the figures - of a measuring apparatus according to the invention comprises at least one microsensor having two chambers 20, 30 filled with a gas, the chambers 20, 30 being connected to one another by a channel 40, the chambers 20, 30 moreover being sealed off to the outside in a gastight manner, and a detection device 70 for detecting a gas stream flowing in the channel 40 being provided, which gas stream arises on account of different pressures prevailing in the chambers. The detection device 70 is assigned a heating/cooling element by means of which the detection device can be heated or cooled to a measurement temperature which differs from the temperature of the gas in the chambers 20, 30.

In the case of the exemplary embodiment shown in the figures, the two chambers 20 and 30 are situated in a semiconductor substrate 10. The chambers 20 and 30 preferably have dimensions in the millimeters range. By way of example, the chambers 20 and 30 each have a width of one millimeter, a height of two micrometers and a length of three millimeters. The channel 40 connecting the chambers 20 and 30 to one another has a cross-sectional area in the micrometers range, for example from 1 to 10  $\mu\text{m}^2$ . Preferably, the length of the channel is greater than its width by a factor of from 2 to 10. In the present case, the length of the channel 40 is approximately 10  $\mu\text{m}$ .

In order to detect the gas stream, the detection device 70, formed by a resistor, is arranged in the channel 40. The resistor 70, which is heated to measurement temperature by a heating arrangement (not illustrated) or a current passed through it, is cooled by the gas stream passing through the channel 40.

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In order to prevent influences on the signal to be measured caused by the inherent temperature of the microsensor 5, provision is made of a reference detection device 60 formed by a resistor 60. In this case, the resistor 60 is arranged in a reference channel 50, whose dimensions are similar to those of the channel 40. The reference channel 50 is situated parallel

5 length is somewhat shorter, however, with the result that the

10 incorporated together in a bridge circuit (not specifically

15 any desired material. In particular, metals or highly doped

25 or formed in front of an opening in the channel 40 and/or

According to Figure 3A, a support layer 10A, preferably composed of silicon, is covered with a first sacrificial layer 11, composed of SiO<sub>2</sub>. The first sacrificial layer 11 preferably has a thickness of between 0.5 μm and 5 μm.

Afterwards, in accordance with Figure 3A, an electrically conductive patterning layer 12 is deposited for the purpose of forming resistors 60, 70, 80. This layer is preferably composed of doped polycrystalline silicon. The patterning layer 12 is patterned using photolithography and etching methods which are known from semiconductor technology. The patterning is preferably effected such that both the resistors 60, 70 and 80 and their leads 61, 63, 71, 73, 81 and 83 are produced.

After the formation of the resistors 60, 70 and 80 and the leads 61, 63, 71, 73, 81 and 83, a second sacrificial layer 13 is deposited in accordance with Figure 3B. The second sacrificial layer 13 preferably has the same thickness as the first sacrificial layer 11.

In accordance with Figure 3B, a covering layer 14 is applied to the second sacrificial layer 13. The covering layer 14 is composed of polycrystalline silicon, for example. Using photolithography and etching methods which are likewise known from semiconductor technology, the covering layer 14 is provided in regions with etching openings 15, under which a cavity 16 in the form of chambers or channels is fabricated in a subsequent process step.

If appropriate, it is then possible for at least a portion of the areas which are produced in the substrate 10 and form the two chambers 20, 30 and the channel 40 connecting the chambers, and also the reference channel 50, prior to the closure, to be provided with a blocker layer 18 which prevents or at least reduces diffusion of the filling gas into the surrounding semiconductor material 10 (Figure 3C).

By coating the covering layer 14 with a covering material 17 -  
15 for example flowing glass (preferably borophosphorus silicate  
glass, BPSG) - and subsequent flowing, the etching openings 15  
in the covering layer 14 are closed off in accordance with  
Figure 3C. With BPSG it is expedient to carry out this flowing  
process at a temperature of approximately 800°C to 1100°C.

The closure is effected in a gas atmosphere, if appropriate at relatively high pressures, in order to fill the chambers with a desired gas.

25 The method of operation of the measuring apparatus according to the invention, said measuring apparatus operating as an acceleration sensor, is explained in more detail below.

In accordance with the barometric height formula

30  $p = p_0 \exp \left[ \frac{\rho_0 g_0}{p_0} h \right]$  the pressure in a gas column is dependent on

the relative density  $\rho_0$  of the gas, the acceleration  $g_0$  and the height  $h$ . For a sealed system having small dimensions, the following holds true for the pressure  $p = p_a + \rho_a g h_a$ , where  $h_0$



of the diaphragm by 1% of the chamber thickness  $a$ , a gas column having the following length flows past the resistor 70:

$$\Delta p = \frac{p_0 \cdot \Delta V}{V} = 10^5 \text{ Pa} \cdot 0.01 = 10^3 \text{ Pa}.$$

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$$L_{\text{gas column}} = V \cdot \frac{\Delta p}{p_0} \cdot \frac{1}{a} = 3 \times 10^3 \times 10^3 \times 2 \mu\text{m}^3 \cdot 0.01 \cdot \frac{1}{1 \mu\text{m}^3} = 6 \cdot 10^4 \mu\text{m}$$

$V$  = volume of a chamber

Static pressure in the chambers  $p_a = 10^5 \text{ Pa}$

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If the dimensions of the chambers 20, 30 are reduced to, for example,  $100 \times 100 \times 2 \mu\text{m}^3$ , then a gas column having a length of  $200 \mu\text{m}$  flows past the resistor. This means that a very sensitive pressure measuring system can be constructed with a chamber area of just  $0.01 \text{ mm}^2$ . As in the case of an accelerometer, the derivative of the pressure is measured in this case, too. In order to obtain the pressure as an output quantity, the electronic signal evaluation comprises integration of the signal.

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If both chambers 20, 30 are bounded by an elastic diaphragm, then a differential pressure sensor can also be constructed with the arrangement according to the invention.

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A further configuration of the microsensor illustrated in the figures as a temperature sensor is possible for example by one of the chambers being provided with a layer which absorbs thermal radiation, while the other chamber is configured in such a way that it reflects thermal radiation. Thus, a very sensitive temperature measuring system can be constructed with this arrangement. If the total temperature in a chamber is

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increased by 1°C, for example, then a gas column having the following length flows past the resistor 70:

$$\frac{P \cdot V}{T} = \text{const}; V = \text{const}.$$

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$$\frac{\Delta p}{p} = \frac{\Delta T}{T} = \frac{1}{300}$$

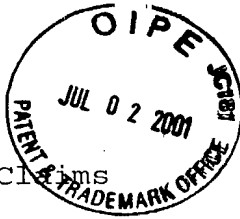
$$L_{\text{gas column}} = V \cdot \frac{\Delta p}{p} \cdot \frac{1}{a} = 3 \times 10^3 \times 10^3 \times 2 \mu\text{m}^3 \cdot \frac{1}{300} \cdot \frac{1}{1 \mu\text{m}^3} = 2 \cdot 10^4 \mu\text{m}$$

10    Given a chamber area of just  $0.01 \text{ mm}^2$ , for example, and a  
      temperature change of  $0.1^\circ\text{C}$ , a gas column having a length of  
      as much as  $7 \text{ }\mu\text{m}$  flows past the resistor 70.

The measuring apparatus may also have a multiplicity of the temperature microsensors described arranged in a one- or two-dimensional array, which microsensors are monolithically integrated with the evaluation circuit and by means of which they can be addressed individually. Such an arrangement may be used for example as sensor element in an infrared camera.

Integration with an evaluation circuit is also possible in the other embodiments.

It should be noted that in the measuring arrangement for acceleration, pressure or temperature, the operating pressure  $p_a$  is temperature-dependent owing to  $\frac{P \cdot V}{T} = \text{const.}$ , the consequence of which is that, for a given signal ( $\Delta g$ ,  $\Delta p$ ,  $\Delta T$ ), the length of the gas column depends on the temperature. Corresponding temperature compensation by way of the heating of the resistor 70 can correct this.



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Patent Claims

1. A measuring apparatus having at least one microsensor (5),  
in which measuring apparatus the following holds true:
  - 5 - the at least one microsensor (5) has at least two chambers  
(20, 30) filled with a gas,  
- the chambers (20, 30) are connected to one another by a  
bushing, and  
- the chambers (20, 30) are, moreover, sealed off to the  
10 outside in a gastight manner,  
characterized  
in that the bushing is designed as a channel (40), in which  
there is provided a detection apparatus (70) for detecting a  
gas stream flowing in the channel (40) on account of different  
15 pressures prevailing in the chambers.
2. The measuring apparatus as claimed in claim 1,  
characterized in that the detection device (70) is assigned a  
heating/cooling element by means of which the detection device  
20 can be heated or cooled to a measurement temperature which  
differs from the temperature of the gas in the chambers (20,  
30).
3. The measuring apparatus as claimed in either of claims 1  
25 and 2, characterized in that a change in the temperature of  
the detection device (70) is detected, said change taking  
place on account of the gas stream flowing between the  
chambers (20, 30) through the channel (40), and the detection  
device, as a reaction to this, supplies an electrical  
30 measurement signal at the output (72 and 74) of the detection  
device.
4. The measuring apparatus as claimed in one of claims 2 to  
3, characterized in that the heating/cooling element coupled

to the detection device (70) is formed by an electrical heating resistor, a heating transistor or a heating diode.

5. The measuring apparatus as claimed in either of claims 2 and 3, characterized in that the heating/cooling element coupled to the detection device (70) is formed by a Peltier element.

6. The measuring device as claimed in one of claims 1 to 5,  
10 characterized in that the detection device (70) is formed by a  
thermoelement.

7. The measuring apparatus as claimed in one of claims 2 to  
5, characterized in that the detection device (70) is formed  
15 by the heating/cooling element itself.

8. The measuring apparatus as claimed in one of claims 1 to 7, characterized in that a reference channel (50) which opens only in a chamber (30) is provided, a reference detection  
20 device (60) having predetermined electrical properties being assigned to said reference channel.

9. The measuring apparatus as claimed in one of claims 1 to 8, characterized in that an additional detection device (80) having predetermined electrical properties is assigned to the detection device (70), which additional detection device (80) is heated or cooled by the heated or cooled gas stream, respectively, the temperature of which has been altered by the detection device (70) at the measurement temperature, in the case of the gas stream direction from the detection device (70) to the additional detection device (80), and, as a reaction to this, supplies an electrical measurement signal at its output (82 and 84) and, in the case of a gas stream direction from the additional detection device (80) to the

detection device (70), supplies no measurement signal at its output (82 and 84).

10. The measuring apparatus as claimed in claim 8,  
5 characterized in that the detection device (70) and the reference detection device (80) are connected together in a measuring bridge circuit.

11. The measuring apparatus as claimed in claim 9 or 10,  
10 characterized in that both the detection device (70) and the reference detection device (60) or the additional detection device (80) are arranged in or on an edge region of a wall or are formed so as to comprise the wall.

12. The measuring apparatus as claimed in claim 11,  
15 characterized in that the wall is composed of semiconductor material.

13. The measuring apparatus as claimed in one of claims 9 to  
20 12, characterized in that the chambers (20, 30) and the channels (40, 50) and/or the reference channel (50) of the microsensor (5) are formed in a semiconductor substrate (10).

14. The measuring apparatus as claimed in one of claims 9 to  
25 13, characterized in that the additional detection device (80) is formed within at least one channel (40).

15. The measuring apparatus as claimed in one of claims 1 to  
30 14, characterized in that one of the chambers (20, 30) has an elastic diaphragm effecting sealing-off to the outside.

16. The measuring apparatus as claimed in one of claims 1 to  
15, characterized in that the microsensors (5) are arranged in



20. The method as claimed in claim 18 or 19, characterized in that the covering material (17) is borophosphorus silicate glass (BPSG).

5 21. The method as claimed in claim 17, characterized in that the chambers (20, 30), the at least one channel (40) connecting the chambers, and also the reference channel (50) in the substrate (10) and also the detection device (60) and also the reference and the additional detection devices (70  
10 and 80) are fabricated by the following process steps:

- coating of the substrate (10) with a sacrificial layer (11), for example  $\text{SiO}_2$ ,
- patterning of the detection device (60) and also of the reference and the additional detection devices (70 and 80)  
15 with their leads (61, 63, 71, 73, 81, 83) on the sacrificial layer (11), for example by means of an etching method,
- application of a second sacrificial layer (13),
- application of a covering layer (14), for example made of polycrystalline silicon,
- 20 - provision of the covering layer (14) with holes (15) at least partially in the regions under which the chambers (20, 30) and/or channels (40, 50) are intended to be produced,
- etching out of the two sacrificial layers (11 and 13) through the holes (15) in the covering layer (14) for the  
25 purpose of producing the chambers (20, 30) and/or channels (40, 50).

22. The method as claimed in one of claims 17 to 21, characterized in that at least a portion of the areas which  
30 are produced in the substrate (10) and form the at least two chambers (20, 30) and the at least one channel (40) connecting the chambers, and also the reference channel (50), is provided, prior to closure by means of the covering material (17), with a blocker layer (18) which prevents or at least

reduces diffusion of the filling gas into the surrounding semiconductor material (10).



## Abstract

The invention relates to a measuring apparatus having at least one microsensor (5), in which measuring apparatus the

5 following holds true:

- the at least one microsensor has at least two chambers (20, 30) filled with a gas,
- the chambers (20, 30) are connected to one another by at least one channel (40),
- 10 - the chambers (20, 30) are, moreover, sealed off to the outside in a gastight manner, and
- a detection device (70) for detecting a gas stream flowing in the at least one channel (40) is provided, which gas stream arises on account of different pressures prevailing in the
- 15 chambers.

Furthermore, the invention relates to a method for producing a microsensor according to the invention.

20 (Figure 1)



Practitioner's Docket No. GR 98 P 1307

**PATENT**

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**COMBINED DECLARATION AND POWER OF ATTORNEY**

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL,  
CONTINUATION, OR C-I-P)

---

As a below named inventor, I hereby declare that:

**TYPE OF DECLARATION**

This declaration is for a national stage of PCT application.

**INVENTORSHIP IDENTIFICATION**

My residence, post office address and citizenship are as stated below, next to my name. I believe that I am the original, first and sole inventor (*if only one name is listed below*) or an original, first and joint inventor (*if plural names are listed below*) of the subject matter that is claimed, and for which a patent is sought on the invention entitled:

**TITLE OF INVENTION**

MEASURING DEVICE WITH A MICROSENSOR AND METHOD FOR ITS PRODUCTION

**SPECIFICATION IDENTIFICATION**

The specification is attached hereto.

**ACKNOWLEDGMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR**

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information, which is material to patentability as defined in 37, Code of Federal Regulations, § 1.56.

**PRIORITY CLAIM (35 U.S.C. § 119(a)-(d))**

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's

## SIGNATURE(S)

1-6~  
Wolfgang Werner

Inventor's signature

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certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

Such applications have been filed as follows.

**PRIOR PCT APPLICATION(S) FILED WITHIN 12 MONTHS  
(6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION  
AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119(a)-(d)**

INDICATE IF PCT	APPLICATION NUMBER	DATE OF FILING DAY, MONTH, YEAR	PRIORITY CLAIMED UNDER 35 USC 119
	198 10 286.0	10/03/1998	yes
PCT	PCT/DE99/00286	01/02/1999	yes

**POWER OF ATTORNEY**

I hereby appoint the following practitioner(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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**DECLARATION**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

410 Rec'd PCT/PTO 10 SEP 2001

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Docket No.: GR 98 P 1307 P



UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants : Wolfgang Werner  
Applic. No. : 09/623,924  
Filed : September 11, 2000  
Title : Measuring Apparatus with Microsensor and  
Method for Producing it

RECEIVED

24 SEP 2001

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International Division

**ASSOCIATE POWER OF ATTORNEY**

Hon. Commissioner of Patents and Trademarks,  
Washington, D.C. 20231

Sir:

Please recognize MARK P. WEICHSELBAUM (Reg. No. 43,248) as my associate in the matter in the above-identified application, with full powers. Please continue addressing all communications to the following address:

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Respectfully submitted,

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